Chapter Fifty-Seven

TRAFFIC CONTROL DEVICES

BUREAU OF DESIGN AND ENVIRONMENT MANUAL

Chapter Fifty-Seven
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CHAPTER FIFTY-SEVEN
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57-1 GENERAL

57-1.01 Context

57-1.01(a) *Illinois Manual on Uniform Traffic Control Devices* (*ILMUTCD*)

The *ILMUTCD* information is divided into four categories — standard, guidance, option, and support. Use these categories to determine the appropriate application for the various traffic control devices. The *ILMUTCD* defines these categories as follows:

1. Standard. These are mandatory actions that are required without exception or with exceptions so noted under the standard heading. Typical phrases include shall, shall mean, shall be satisfied, shall consist, etc.

2. Guidance. This category is considered to be advisory usage, recommended but not mandatory. Deviations are allowed where engineering judgment indicates the need. Typical phrases include should, should be, should be considered, should be given, etc.

3. Option. This category includes procedures and devices that are allowed but carry no recommendations or mandate. The designer is free to use or refrain from their use. Typical phrases include may, may be used, may be considered, etc.

4. Support. This category includes all introductory or explanatory language. It may occur before, within, or after any of the above categories. Typical phrases include is, are, warrants, considered, required, etc.

57-1.01(b) IDOT Application

In reference to the *ILMUTCD* categories, the Department has adopted the following positions:

1. Standard. The designer must meet the conditions of the *ILMUTCD*.

2. Guidance. The designer will follow the *ILMUTCD* with very few exceptions. For situations where it is impractical to follow "guidance" criteria, the designer must obtain Departmental approval.

3. Option. The designer should make every reasonable effort to follow the *ILMUTCD* criteria. For situations where it is impractical to follow "option" criteria, Departmental approval is necessary.

57-1.02 References

For information on traffic control device material specifications, design, and application criteria, review the applicable publications listed below:

1. *Illinois Manual on Uniform Traffic Control Devices (ILMUTCD)*, IDOT;
2. *Bureau of Operations Traffic Policies and Procedures Manual*, IDOT;
3. *Standard Specifications for Road and Bridge Construction*, IDOT;
4. *Highway Standards*, IDOT;
5. *Standard Highway Signs* IDOT;
6. *Sign Structures Manual*, IDOT;
7. *A Policy on Geometric Design of Highways and Streets*, AASHTO;
8. *Roadside Design Guide*, AASHTO;
9. *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*, AASHTO;
10. *Manual of Steel Construction*, AISC;
11. *Standard Alphabets for Highway Signs and Pavement Markings*, FHWA;
12. *Traffic Engineering Handbook*, ITE;
13. *Manual of Transportation Engineering Studies*, ITE;
14. *Manual of Traffic Signal Design*, ITE;
15. *Equipment and Materials Standards*, ITE;
16. *Preemption of Traffic Signals At Or Near Active Warning Railroad Grade Crossings*, ITE;
17. *Traffic Signal Installation and Maintenance Manual*, ITE;

18. *Traffic Signing Handbook*, ITE;

19. *Traffic Detector Handbook*, FHWA;

20. *Official Wire and Cable Specifications Manual*, IMSA;

21. *Traffic Control Systems*, NEMA;

22. *Traffic Controller Assemblies*, NEMA;

23. *Highway Capacity Manual*, TRB; and

24. National, State, and Local Electrical Codes and Manufacturer's Literature.

57-2 HIGHWAY SIGNING

57-2.01 Responsibilities

The responsibilities for elements of highway signing projects are as follows:

1. Structural Design. The Bureau of Operations and the Bureau of Bridges and Structures are jointly responsible for establishing Department criteria for the design of structural supports for traffic control devices (e.g., breakaway bases for large signs).

2. Location and Legend. The district Bureau of Operations is responsible for the legends and the initial placement of highway signs, based on proper conveyance of information to the motorist. The roadway designer will review the location of highway signing to ensure that it is compatible with the roadway design.

3. Soil Borings. Projects with large or overhead signs typically will require soil borings. The district is responsible for taking the soil borings.

4. Plan Preparation. The district Bureau of Operations is responsible for preparing the highway signing detail sheets to be included in the plans. See Chapter 63 for additional information on plan preparation.

57-2.02 References

For additional information on highway signing material specifications, design, and application criteria, review the applicable publications listed in Section 57-1.02.

57-2.03 Sign Placement

57-2.03(a) General

Placement criteria for highway signs next to and/or over the roadway is documented in the *Bureau of Operations Traffic Policies and Procedures Manual* and the *ILMUTCD*. Additional guidance can be found in the publications listed in Section 57-1.02 and Chapter 38. Uniform placement of highway signing, although desirable, is not always practical because highway alignment and other factors often dictate a more advantageous location. When determining sign locations, consider the following guidelines:

1. Special Locations. Normally, signs should be placed on the right side of the roadway. Under certain circumstances, however, signs may be placed on channelizing islands, overhead structures, or on the left side of the roadway along sharp, right-hand curves, or on the left side of multi-lane highways.

2. Dual Signing. Consider dual signing on one-way or divided roadways (i.e., on both sides of the traveled way) for additional emphasis where a single sign may not provide adequate warning and where roadway geometry or other factors (e.g., multiple lanes, trucks, parked vehicles) may cause a single sign to be obscured.

3. Geometric Design. Coordinate sign placement and geometric design as early as practical during project planning and design. A geometric design may need to be revised if it does not accommodate adequate sign placement.

4. Overhead Lane Control. Where lane control is desired, place signs directly over the affected lane. For additional information, see the *Bureau of Operations Traffic Policies and Procedures Manual*, *ILMUTCD*, and the publications listed in Section 57-1.02.

5. Nighttime Visibility. Locate signs to optimize their nighttime visibility.

6. Field Conditions. Adherence to desired placement is not always practical. Adjust sign locations to accommodate actual field conditions and try to avoid the following problem areas:

   - at short sags in the roadway,
   - beyond the crest of a vertical curve,
   - where a sign would be obscured by parked cars,
   - where a sign would create an obstruction for pedestrians or bicyclists,
   - where a sign would obscure visibility of hazardous locations,
   - where the visibility of a sign would be impaired by overhead illumination,
   - where a sign would be vulnerable to roadside splatter or snow from plowing operations, and/or
   - at locations close to foliage where the sign face may be covered.

7. Longitudinal Placement. In some cases, signs can be shifted longitudinally without compromising their intended purpose. This may improve their visibility and enhance safety.

8. Sign Groups. In general, signs are mounted individually on supports. However, it may be necessary to erect a sign grouping (e.g., route markings). Consider wind loading and breakaway criteria when designing sign groups.

9. Lateral Clearance. The *Bureau of Operations Traffic Policies and Procedures Manual*, *ILMUTCD*, and the publications in Section 57-1.02 provide the criteria for the lateral clearance of signs. In addition, see Section 57-2.04.

57-2.03(b) Placement of Advance Warning Signs

Warning signs are used to warn drivers of potentially hazardous conditions on or adjacent to the roadway. They are placed in advance of the conditions to which they apply. Warning signs should be used sparingly. Use of warning signs at non-hazardous locations tends to cause non-compliance of all signing. If the distances in Part II of the *ILMUTCD* cannot be met, then consider other measures to attract the motorist's attention to the sign (e.g., flashing beacons, distance plates).

57-2.04 Roadside Safety

For roadside safety applications, the following will apply to highway signs:

1. Design. The *Illinois Highway Standards* and *Sign Structures Manual* contain the Department's details for structural supports for traffic control devices.

2. Ground-Mounted Sign Supports. Supports for ground-mounted signs shall be made breakaway or yielding. Large signs over 50 ft^2 (5.0 m^2) in area should have breakaway supports, whether within or outside the clear zone. Where practical, locate signs behind a roadside barrier that is warranted for other reasons. Provide adequate clearance to the back of the guardrail post to accommodate the barrier's dynamic deflection (see Section 38-6). In addition, do not place breakaway sign supports in drainage ditches where erosion and freezing might affect the proper operation of the support. It is also possible that an errant vehicle entering the ditch might be inadvertently guided into the support. If placed on a back slope, offset these supports at least 5 ft (1.5 m) from the toe of the back slope of the ditch.

57-2.05 Overhead Signs

In addition to the requirements covered in the *ILMUTCD,* consider the following guidelines for overhead signing applications:

1. Lane Control. Consider using overhead signs where the message is applicable to a specific lane. If the sign is placed over the lane, lane use can be made significantly more effective, especially in areas where channelization does not meet the driver's expectations and where additional guidance is required for unfamiliar drivers. Locate overhead signing in advance of the intersection. Lane control signing may be located on the signal mast arm where justified by sight conditions.

2. Driver Unfamiliarity. Consider overhead signing in areas where there is a high volume of tourist traffic.

3. Visibility. Use overhead signs where traffic or roadway conditions are such that an overhead mounting is necessary for adequate visibility (e.g., vertical or horizontal curves, closely spaced interchanges, two or more through lanes in one direction). In addition, consider the visual acuity of elderly drivers.

4. Divergent Roadways. Place overhead signs in advance of and/or at a divergence from a heavily traveled roadway (e.g., at a ramp exit where the roadway becomes wider).

5. Exits. Consider the application of overhead signing where non-uniform exit maneuvers exist (e.g., left-hand or multi-lane exit ramps).

6. Interchanges/Intersections. Use overhead signs at complex interchanges where driver confusion is exhibited, where interchanges are closely spaced, at Interstate-to-Interstate interchanges and/or where there are lane drops on the exit ramp or mainline within the interchange. Consider overhead signing also on the approach to intersections of two major arterial streets.

7. Trucks. Signs may be mounted overhead where there is a significant number of large trucks.

8. Limited Right-of-Way. Use overhead signs where there is limited space for signs on the roadside (e.g., where right-of-way is narrow).

9. Roadside Development. Consider overhead signs at locations where roadside development seriously detracts from the effectiveness of roadside signs.

10. Uniformity. Signs should be mounted overhead for consistency with other signs on a given section of highway.

11. Overhead Sign Supports. All overhead signs will use non-breakaway supports. Within the clear zone, conduct a cost-effectiveness analysis to determine if these structures should be protected with a roadside barrier or, where applicable, with an impact attenuator. In addition, consider placing overhead signs on bridges to eliminate the need for supports. Consult the Bureau of Bridges and Structures for guidance.

57-2.06 Vertical Clearance

New installations of overhead signs will require a minimum vertical clearance of 17 ft 3 in (5.25 m) above the roadway and shoulders. This includes an additional 4 in (100 mm) clearance for a future pavement surface overlay. Existing overhead signs may have a vertical clearance of 16 ft 9 in (5.10 m).

57-3 PERMANENT PAVEMENT MARKINGS

57-3.01 Responsibilities

The designer is responsible to provide for the initial placement of pavement markings (e.g., striping, symbols) and the development of the pavement marking detail sheets for insertion into the plans. The district Bureau of Operations will review the pavement marking details. The designer will incorporate the pavement marking details into the final highway plans.

57-3.02 References

For additional information on permanent pavement marking material specifications, design, and application criteria, review the applicable publications listed in Section 57-1.02

57-3.03 Line Types

Line types vary depending on their application. See the *Bureau of Operations Traffic Policies and Procedures Manual*, *ILMUTCD,* and the publications listed in Section 57-1.02 for specific application criteria. Consider the following when developing pavement marking details for permanent roadway application:

1. Reflectorization. Pavement markings normally will be reflectorized.

2. Color. Pavement markings will be either white or yellow conforming to the standard highway color specifications. For example, word and symbol markings, crosswalk lines, most channelization lines, stop lines, parking space lines, and all lane lines will be white in color. Center lines, no-passing barrier lines, and medians will be yellow.

3. Material. See Department Policy TRA-14, "Guidelines for the Use of a Pavement Marking Materials on State Highways."

4. Orientation and Style. Line types will vary in thickness and width; will be oriented in a longitudinal, transverse, or diagonal configuration; and will be striped as either single or double lines in a solid, broken, or dotted pattern.

57-3.04 Traveled Way Markings

The following sections present typical traveled way marking applications. Guidelines for line size, color, and placement can be found in the *ILMUTCD* and the *Bureau of Operations Traffic Policies and Procedures Manual*.

57-3.04(a) Center Lines

Center lines are used to separate vehicles traveling in opposite directions. Locate center lines on either side of a longitudinal pavement joint. This will minimize the need for remarking after a joint-sealing operation.

57-3.04(b) Lane Lines

Lane lines are used to separate lanes of traffic traveling in the same direction. Use a broken white line for two or more lanes in the same direction. A solid white line may be used to discourage lane switching (e.g., approaches to signalized intersections). To facilitate future maintenance operations, offset all lane lines from longitudinal construction joints.

57-3.04(c) Edge Lines

Edge lines are used to delineate the edge of traveled way. Left-hand edge lines are median lines, except on one-way streets, and are discussed further in Section 57-3.04(d). Where the application of a right-hand edge line is justified, use a solid white line.

57-3.04(d) Median Lines

Median lines are required on all multilane divided highways. Provide gaps at all intersections and median crossovers.

57-3.04(e) Channelizing Lines

Channelizing lines are used to separate traffic movement into definitive paths to facilitate safe and orderly movement. Channelizing lines may be used to separate opposing traffic (e.g., left-turn bays), or to separate traffic traveling in the same direction (e.g., gore areas). Channelizing lines also may be used to emphasize a flush or raised-curb median.

57-3.04(f) Transitions

Where transitions are necessary, pavement markings are used to guide the motorist through the transition area. See the *Bureau of Operations Traffic Policies and Procedures Manual* and the *ILMUTCD* for the applicable taper rate and length criteria at transitions (e.g., auxiliary lane tapers, beginning taper for left- and right-turn lanes, Interstate exits).

57-3.04(g) No-Passing Lines

A no-passing line is a special type of center line; see Section 57-3.04(a). Place a solid yellow line adjacent to the lanes that warrant the no-passing restriction. Provide no-passing lines along vertical and horizontal curves and elsewhere on two-lane facilities where the driver's line-of-sight is less then the minimum passing sight distance criteria presented in the *ILMUTCD*. The values presented in the *ILMUTCD* should not be confused with the passing sight distances presented in the AASHTO publication *A Policy on Geometric Design of Highways and Streets* which are geometric design criteria based on an assumption that a passing vehicle will be able to complete its passing maneuver. The minimum passing sight distance criteria presented in the *ILMUTCD* are sufficient to allow a passing vehicle to abort its passing maneuver. See Chapter 32 and Chapter 33, respectively, for horizontal and vertical curve design criteria. Conduct a review of successive no-passing zones to ensure that the roadway section will be properly striped (e.g., eliminating less than minimum gaps).

57-3.05 Intersections

Chapter 36 discusses intersection design. The following sections present typical intersection pavement marking applications. See the *ILMUTCD* and the *Bureau of Operations Traffic Policies and Procedures Manual* for line size, color, and placement guidelines.

57-3.05(a) Stop Lines

The stop line is a transverse line that is used to indicate where the desired vehicular stopping point is located. Under certain circumstances, the location of the stop line may be adjusted to fit field conditions. For example, where turning trucks are known to encroach into the opposing lane, place the stop line outside the area of frequent encroachment. On multilane facilities that intersect the crossroad at an angle, it may be appropriate to stagger the stop line for each lane. This consideration is especially important at signalized intersections which may have substantial clearance times. Consult the Bureau of Operations for additional guidance.

57-3.05(b) Channelizing Markings

Channelizing markings are used to emphasize the appropriate direction of travel. Depending on their use, they may be either white or yellow solid lines.

57-3.05(c) Crosswalks

An engineering study should be used to determine the need for proper location of crosswalks. Typical locations where marked crosswalks are used include:

- points of significant pedestrian concentration,
- signalized or unsignalized intersection approaches, and
- traffic stops that channelize pedestrians into identified corridors.

The crosswalk must encompass all curb ramps to satisfy the accessibility criteria; see Chapter 58.

57-3.05(d) Lane-Use Control Markings

At multilane approaches to intersections, it is often necessary to mark the intersection approach to designate the permitted movements through the intersection. This is especially important at intersections that have complex geometrics and multi-phase signal operations (e.g., exclusive turn lanes, drop lanes, dual left-turn lanes). Consider using lane-use control markings at the following locations:

- where the number of lanes approaching an intersection do not continue through to the opposite side of the intersection (e.g., auxiliary turn lanes);

- at major signalized intersections;

- where there exists an abnormal traffic pattern for an intersection approach; or

- where there is a possibility of confusion at an intersection or unusual conditions prevail.

57-3.05(e) Multiple Turn Lanes

At intersections that have multiple turn lanes (e.g., dual left-turn lanes), a series of single dotted lines may be used to guide the turning traffic through the intersection. These lines are typically an extension of the lane line and, therefore, are white in color. The radius of the dotted line as extended through the intersection should be sufficient to accommodate the turning radius of the design vehicle.

57-3.06 <u>Interchanges</u>

Use pavement markings at interchanges to properly guide the motorist on and off of the high-speed facility (e.g., exit and entrance ramps, gore areas). See the *Bureau of Operations Traffic Policies and Procedures Manual, ILMUTCD,* and the specific application criteria for pavement markings at interchanges. Chapter 37 provides the criteria for interchange design.

57-3.07 Miscellaneous Marking Applications

57-3.07(a) Special Markings

Special markings (e.g., words, symbols, arrows) are used to guide, warn, and regulate traffic. Where used in a regulatory setting, these special markings are used to supplement the appropriate regulatory signing. Typical applications of special markings include:

- lane-use control at multilane intersections;
- highway-railroad grade crossings;
- school crossings;
- stop-controlled intersections;
- two-way, left-turn lanes;
- interchange ramps;
- one-way roadways;
- word markings; and
- directional arrow markings.

See the references in Section 57-1.02 for design and application criteria for special markings.

57-3.07(b) Truck-Climbing Lanes

For facilities with truck-climbing lanes, the center line will be a broken yellow line, a double yellow line consisting of a broken line and solid line, or a double solid yellow line. Provide a broken white lane line between the normal travel lane and the climbing lane. Transition the edge line to the outside edge of the climbing lane. See the *Bureau of Operations Traffic Policy and Procedures Manual* for additional pavement marking application criteria for truck-climbing lanes.

57-3.07(c) Two-Way, Left-Turn Lanes (TWLTL)

On TWLTL's, the center lane is reserved for the exclusive use of a bi-directional, left-turn movement. The TWLTL is designed to harbor left-turning vehicles in the median area until a gap in the opposing traffic stream becomes available. The *Bureau of Operations Traffic Policies and Procedures Manual* and the *ILMUTCD* provide the pavement marking application criteria for two-way, left-turn lane facilities.

57-3.07(d) School Crossings

Mark school crossings according to the criteria presented in the *ILMUTCD*. See the publications in Section 57-1.02 for additional criteria. Pavement markings for school crossings should be used only with the appropriate signing. The proper signing should be in place, if practical, at the time the pavement markings are placed.

57-3.07(e) Highway-Railroad Grade Crossings

Place pavement markings in advance of railroad-highway grade crossings according to the criteria in the *ILMUTCD*. See the publications in Section 57-1.02 for specific design and application criteria.

57-3.07(f) Bicycle Facilities

The color and type of lines used for bicycle facilities will be the same as that determined for automobiles (e.g., broken yellow line for two-way bike paths). Broken lines for bicycle paths should have a 1 to 3 ratio (e.g., 3 ft (1 m) segment with a 10 ft (3 m) gap). Use a solid white line to separate pedestrians and bicycles if they share a common facility. Use the preferential bike-lane symbol, as defined in the *ILMUTCD*, where a separate bike lane is provided on a vehicular roadway. See the references in Section 57-1.02 for specific design and application criteria for bicycle facilities. Chapter 17 provides additional information on pavement markings for bicycle and pedestrian facilities.

57-3.07(g) Rest Areas/Weigh Stations

For the design, marking, and striping criteria for rest areas and weigh stations, see Chapter 16, the Bureau of Operations *Traffic Policies and Procedures Manual* and the *ILMUTCD.*

57-3.07(h) On-Street Parking

Where used, on-street parking should be marked a sufficient distance back from an intersection so as not to obscure, or otherwise diminish, sight distance at the intersection and to minimize interference with the flow of vehicles and pedestrians. The publications in Section 57-1.02 provide additional guidance on on-street parking.

57-4 TRAFFIC SIGNALS

57-4.01 Responsibilities

57-4.01(a) State Projects

The following will apply to traffic signals on State projects:

1. Signal Design. The district will be responsible for the design of the traffic signal and for preparing the traffic signal detail sheets to be included in the plans. The district also will coordinate with any involved local agency to ensure that the selected traffic signal equipment can be maintained by that agency.

2. Structure Design. The central office Bureau of Operations and the Bureau of Bridges and Structures are jointly responsible for establishing the Department criteria for the design of traffic signal structural supports.

3. Review. The central office Bureau of Operations will be responsible for reviewing the traffic signal design for conformance with Department criteria.

4. Road Designer. The road designer will be responsible for reviewing the location of the traffic signal equipment (e.g., controller cabinet, signal supports) to ensure that they are compatible with the roadway design.

5. Signal Phasing and Timing. The district will be responsible for preparing the signal phasing and timing designs for the traffic signal.

6. Agreements. The district will be responsible for preparing any necessary agreements between the State and the local agency for the operation and maintenance of the traffic signal; see Chapter 5.

57-4.01(b) Local Projects

Where a local agency places a traffic signal on a State or Federal route or where an exit or entrance ramp intersects with a local facility, the Department will be responsible for reviewing the plans to ensure that they are in conformance with Department criteria. The local agency will be responsible for design of the traffic signal and for preparing the traffic signal detail sheets.

57-4.02 References

For additional information on traffic signal equipment and material specifications, design, and application criteria, review the applicable publications listed in Section 57-1.02.

57-4.03 Definitions

The following list of definitions supplements those found in the various references of commonly used terms in traffic signal design:

1. Active Grade Crossing Warning System. The flashing signals, with or without warning gates, together with the necessary control equipment used to inform road users of the approach or presence of trains at highway-railroad grade crossings.

2. Approach. All lanes of traffic moving toward an intersection or a mid-block location from one direction, including any adjacent parking lane(s).

3. Call. The result of the actuation of a vehicle or pedestrian detector.

4. Network. A geographical arrangement of intersecting roadways.

5. Platoon. A group of vehicles or pedestrians traveling together as a group either voluntarily or involuntarily because of traffic signal controls, geometrics, or other factors.

6. Ramp Control Signal (Ramp Meter). A traffic control signal installed to control the flow of traffic onto freeways at entrance ramps and freeway-to-freeway connections.

7. Right-of-Way (Assignment). Permitting vehicles and/or pedestrians to proceed in a lawful manner in preference to other vehicles or pedestrians by the display of signal indications.

8. Signal Installation. The traffic signal equipment, signal heads and their supports, and associated electrical circuitry at a particular location.

9. Signal Section. The assembly of a signal housing, lens, and light source with necessary components and supporting hardware to be used for providing one signal indication.

10. Signal System. Two or more traffic control signal installations operating in coordination.

11. Steady (Steady Mode). The continuous illumination of a signal indication for the duration of an interval, phase, or consecutive phases. The steady mode is used when a signalized location is operated in a stop-and-go manner.

12. Visibility-Limited Signal Indication. A type of signal face, signal section, or signal indication designed to restrict the visibility of a signal indication from the side, or to limit the visibility of a signal indication to a certain lane or number of lanes or to a certain distance from the stop line.

57-4.04 <u>Traffic Signal Warrants</u>

57-4.04(a) New Traffic Signals

The investigation of the need for a traffic signal includes an analysis of the applicable warrant factors contained in the *ILMUTCD* and other factors related to safety and operation at the study location.

If none of the warrants are satisfied, then a traffic signal should not be considered at the study location. Furthermore, the satisfaction of one or more of the warrants does not in itself justify the installation of a traffic signal. An engineering and traffic study of the site's physical characteristics and traffic conditions is necessary to determine whether a traffic control signal installation is justified at a particular location.

57-4.04(b) Existing Traffic Signals

If it is obvious that an existing traffic signal meets one or more of the traffic signal warrants, then no special documentation will be required.

The Phase I report should document whether the existing signals should be removed or retained based on the following as well as other supporting information:

- percent of warrants met,
- expected development and traffic growth on intersecting streets,
- signal progression with adjacent signals, and
- crash potential due to either retention or removal of the signal.

57-4.05 <u>Traffic Signal Needs Study</u>

Although one or more of the warrants presented in *ILMUTCD* may be satisfied, the results of a thorough engineering and traffic study of the site's physical characteristics and traffic conditions may indicate that the installation of a traffic signal is not the most prudent choice. A traffic signal should not be installed unless an engineering study indicates that installing the device will improve the overall safety and/or operation of the intersection. In addition to the *ILMUTCD* traffic signal warrants, consider the following factors:

1. <u>Crash Experience</u>. Consider alternative solutions to crash-related problems (e.g., removing parking, using advance warning signs or larger signs).

2. <u>Geometrics</u>. The intersection's geometric design can affect the efficiency of the traffic signal. Traffic signal installations at poorly aligned intersections may, in some cases, increase driver confusion and reduce the overall efficiency of the intersection. If

practical, properly align the intersection to adequately accommodate turning lanes, through lanes, etc. See Chapter 36 for the geometric design criteria of intersections.

3. Costs. The installation and maintenance of traffic signals can be very expensive. A cost-effectiveness analysis may be necessary to determine if the benefits from the reduction in crashes and delays will actually exceed the costs associated with signalization.

4. Location. Consider the intersection relative to the adjacent land use type and density (e.g., urban, suburban, rural) and the potential for future development in the study area. Also consider the location of the intersection within the context of the overall transportation system (e.g., isolated locations, interrelated operations, functional classification). Normally, isolated locations are intersections where the distance to the nearest signalized intersection or potential future signalized intersection is greater than 0.5 mile (800 m).

5. Approach Geometrics and Volumes. For the purpose of comparing intersection conditions to the warrants, lanes added on major streets within 300 ft (90 m) of the intersection should not be considered as approach lanes unless a significant volume of traffic enters the streets within the added lane (e.g., ramp connection).

6. Temporary Signals. The need for temporary traffic signals will be determined on a case-by-case basis. These installations are typically considered for construction and maintenance projects. Use the warrants for permanent signal installations as guidelines to determine temporary signal needs. As practical, design temporary traffic signals consistent with the design criteria for permanent signal installations.

7. Design Year. Consider the design year during the study and assess the potential for future expansion at the intersection (e.g., construction of additional approach lanes).

8. Removal of Confusing Advertising Lights. Advertising lights, or other similar devices located adjacent to the roadway, that are similar in color to traffic signal indications, often can be mistaken for traffic signal control, interfere with the effectiveness of a traffic signal, and possibly contribute to driver confusion and crashes. Where this appears to be a problem, contact the property owner and local officials to explain the problem and possible solutions.

9. Provisions for Future Installations. Consider the future needs of the study location. Assess the anticipated traffic growth and future operational requirements of the signalized location during planning and design, as practical, so that later modifications can be readily incorporated and total labor and material costs minimized. Traffic signal equipment should be specified with some degree of operational flexibility to accommodate future needs. This is illustrated by the following examples:

a. If predicted traffic growth is likely to require a left-turn lane in the future, the design should accommodate this future need (e.g., equipment, phasing, circuitry, pole mounting).

b. If a street will be widened or an intersection will be reconstructed in the foreseeable future, consider either a temporary signal or, if possible, an installation that conforms to the proposed final layout.

c. If a need for a signal interconnect or additional phases can be foreseen, then provisions for these situations should be incorporated in the initial design.

57-4.06 Traffic Signal Operation

A traffic signal controller is an electronic device mounted in a cabinet for controlling the sequence and phase duration of the traffic signal. Right-of-way is assigned by either energizing or de-energizing the green indication. See the *Standard Specifications for Road and Bridge Construction*, *Bureau of Operations Traffic Policies and Procedures Manual* and the *ILMUTCD* for specifications, design, and application criteria of traffic signal controllers. The following sections provide general information on the various controller operations.

57-4.06(a) Pretimed Operation

A pretimed operation uses a fixed, consistent predetermined cycle length. There can be several different timing programs based on the time-of-day and/or day-of-week. A pretimed operation is best suited where traffic volumes and patterns are consistent from day-to-day (e.g., downtown areas), where variations in volumes are predictable, and where control timing can be preset to accommodate variations throughout the day.

57-4.06(b) Semi-Actuated Operation

Semi-actuated operation is based on vehicular detection from one or more approaches, but not on all approaches. Typically, vehicular detectors (e.g., loop detectors) are placed only on the minor approaches where traffic is light and sporadic. The major approaches are kept in the green phase until a vehicle on the minor approach is detected. If there is a demand on the minor approach and the minimum green time for the major approach has elapsed, the right-of-way then will be given to the minor approach. To accommodate various fluctuations on the minor approach, the minor approach is given enough time to clear one vehicle with additional time added for each new detection up to the maximum green time. Once the minor approach demand has been satisfied or when the maximum green time has been reached, the right-of-way then is returned to the major approach and the cycle begins again. If there is no minor approach demand, the major approach will remain in the green phase indefinitely.

Typical locations for semi-actuated operation include:

- school crossing intersections,
- on access routes to industrial areas or shopping centers,
- on access routes to recreational areas or sport centers,
- on cross streets with poorly spaced signals along the major route, and
- on cross streets with minimal traffic volumes.

57-4.06(c) Fully Actuated Operation

A fully actuated operation has detection devices on all approaches to the signalized intersection. The green interval for each street or phase is determined on the basis of volume demand. Continuous traffic on one street is not interrupted by a detector actuation from the side street until a gap in the traffic appears or when the preset maximum green time has elapsed. Once the minor street demand has been satisfied, right-of-way typically is returned to the major street whether or not a major street detection has been registered. Under heavy demand on all approaches, the intersection tends to operate as a pretimed signal.

A fully actuated operation is an appropriate design choice:

- at isolated locations where volumes on intersection legs are approximately equal with sporadic and varying traffic distribution,

- at locations where traffic signal control is warranted for only brief periods of the day,

- at locations where turning movements are heavy during specific time periods but are light at other times, and

- at high-speed locations where there is a need to avoid “dilemma zone” problems; see Section 57-4.11(c).

57-4.06(d) Actuated Operation with Density Feature

The density feature is an enhancement to the actuated operation. Additional detectors are placed in advance of the intersection to determine both the number of waiting vehicles and vehicular gaps. The density feature permits the controller to adjust the initial portion of the green time to allow the queue of waiting vehicles that arrived during the yellow and red phases to clear the intersection. Once the initial queue is cleared, the allowable vehicular gap in moving traffic is reduced over time giving greater priority to conflict calls from the side street. When vehicular gaps are too long or the preset maximum green time has elapsed, the right-of-way then is given to the queued vehicles on the side street.

57-4.06(e) Pedestrian Control

The traffic signal controller is equipped to safely assign intersection right-of-way to various combinations of both vehicular and pedestrian traffic movements. This flexibility allows the designer to accommodate a pedestrian demand at the intersection by phasing and timing pedestrian WALK and DON'T WALK intervals. These intervals can be either pretimed or actuated by a pedestrian push button; see Section 57-4.07(e). Depending on the intersection design, bicyclists may negotiate the intersection either as a pedestrian or as part of the rolling traffic flow. See Section 57-4.07(f) for additional information on bicycle detection.

57-4.06(f) Special Operation

There are several specialty operations that may be used in a traffic signal design (e.g., flashing mode, signal preemption for emergency and non-emergency priority vehicles, and at highway-railroad grade crossings). These operations should be determined on a case-by-case basis.

57-4.07 Traffic Detectors

The efficient operation of a traffic-actuated signal installation depends greatly upon the proper design and placement of traffic detectors. See the applicable references in Section 57-1.02 for specifications, design, and application criteria for traffic detectors. The following sections provide general information on the various detector types.

57-4.07(a) Detector Operation

The primary purpose of a traffic detector is to detect the presence of a motor vehicle, bicyclist, or pedestrian or to detect the passage of a moving vehicle. The detector actuation is transmitted to the controller which adjusts the signal indications accordingly. There are many types of detector devices available. The inductive loop detector generally is accurate, and is preferred because it can be used for passage or presence detection, vehicular counts, and vehicular speed determination. Traffic detectors can operate in several different modes as follows:

1. Passage (Pulse) Detection. Use passage detection to detect the passage or movement of a vehicle over a particular point. The detector will transmit a short-duration (pulse) output signal for each vehicle detected. The inductive short-loop design (short detection area) normally is operated as a passage detector.

2. Presence Detection. Use presence detection to detect when a vehicle is stopped or is within a particular area. A signal output is transmitted by the detector for as long as a vehicle is within the monitored area (subject to an eventual tuning out of the call by some

devices). The inductive long-loop design (long detection area) normally is operated as a presence detector.

3. Locking Mode. The detector, or the controller memory, holds a call in waiting until the call has been satisfied by a green interval, even though the calling vehicle already may have vacated the approach (e.g., vehicle turning right on red).

4. Non-Locking Mode. For non-locking operation, a call only is held while the detection area is occupied, which then is voided when the vehicle leaves the detection area. The non-locking mode typically is used in presence detection design (e.g., permissive left-turn lanes).

5. Delayed Detection. Delayed detection requires a vehicle to be located in the detection area for a preset time before a detection is recorded. If the vehicle leaves the detection area before the time limit is reached, no detection is recorded. This application is appropriate where right-turns-on-red are allowed.

6. Extended-Call or Stretch Detection. With extended-call detection, a call is held even after the vehicle has left the detection area. This design typically is used to allow the passing vehicle to reach a predetermined point beyond the detection zone before the call is terminated. With modern controllers, extended-call detections may be serviced by the controller software.

57-4.07(b) Inductive Loop Detector

An inductive loop detector design consists of two or more turns of wire embedded below the pavement surface. As a vehicle passes over the loop, it disrupts the magnetic field associated with the current running through the wire. This disruption is recorded by a detector amplifier and is transmitted to the controller as a vehicular detection. The advantages of loop detectors are that they can:

- detect vehicles in both presence and passage modes,
- be used for vehicular counts and speed determinations, and
- be easily designed to meet various site conditions.

A major disadvantage of the loop detector is that it is very vulnerable to pavement surface irregularities (e.g., potholes and cracks) which can cause breaks in the loops.

57-4.07(c) Preformed Loop Detector

The preformed loop detector consists of a detector wire sealed with asphalt rubber or waterproof flexible sealant inside a conduit made of heavy-duty reinforced rubber hose or rigid plastic. This detector may be placed on a base course and covered by a bituminous or concrete surface course. This detector may also be placed within a concrete slab by attaching it to the reinforcing steel and pouring the concrete slab, encasing the detector. The preformed loop detector works the same way as the inductive loop detector.

Preformed loop detectors should be considered in situations where saw-cutting of pavement is impractical or impossible, such as in bridge decks or gravel road approaches to signalized intersections. This detector should be considered for use in concrete pavement because of pavement cracking associated with sawed loops.

57-4.07(d) Video Image Detector

The video image detector consists of one or more video cameras and an automatic control unit. The control unit detects a vehicle by comparing the images from the camera(s) to those stored in memory. The detector can work in both the presence and passage modes. This detector also allows the images to be used for counting and vehicular classification. Special housings are required to protect the camera from environmental elements. This detector should be considered for use with concrete pavement because of pavement cracking associated with sawed loops. Early models experienced problems during adverse weather conditions (e.g., wind, fog, rain, snow); however, recent versions have successfully all but eliminated these problems.

57-4.07(e) Pedestrian Detectors

The most common pedestrian detector is the pedestrian push or call button. Locate pedestrian call buttons so that they are convenient to use and reachable by the disabled. Inconvenient placement of pedestrian detectors is one of the reasons that pedestrians choose to cross the intersection illegally and unsafely.

57-4.07(f) Bicycle Detectors

The two most common devices for bicycle detection include:

1. <u>Pedestrian Push-Button Detector</u>. With the push-button detector, the bicyclist must stop and push the detector button for the controller to record the call. This may require the bicyclist to leave the roadway and proceed on the sidewalk to push the detector button.

2. <u>Inductive-Loop Detector</u>. The inductive-loop detector (e.g., quadrupole) can detect the bicycle without the bicyclist's interaction. To ensure detection, the bicyclist should be guided directly over the loop wire. A problem with using inductive loop(s) for bicycle detection is that they require a significant amount of metal to be activated. Today's bicycle designs tend to use a substantial amount of non-metallic, man-made materials to

increase their strength and reduce their weight. This substantially has reduced the amount of material that can be detected in bicycles.

57-4.08 Traffic Signal Mounting

Under most circumstances, traffic signals typically are mounted on mast arms that are placed on the far side of the intersection. This allows better location and alignment of signal heads for various lane configurations. In addition, the rigid mounting also allows for better control of the signal heads under wind-loading conditions.

Under certain circumstances, pedestal- or post-mounted signals may be used (e.g., left-turn signal in median). See the IDOT publications in Section 57-1.02 for application and placement criteria on post-mounted signals in medians.

Under some temporary situations (e.g., temporary traffic signals in construction zones), signal heads may be mounted on span wires. Some problems with using span wire designs include:

- they do not provide enough rigidity under wind-loading conditions,
- the signal faces are difficult to see on narrow streets,
- pedestrians have difficulty seeing the signal faces, and
- installations are often considered to be aesthetically displeasing.

Consequently, span wire designs typically are not used for permanent installations. See the applicable references in Section 57-1.02 for specifications on mounting materials and for design and application criteria for typical traffic signal mounting.

57-4.09 Placement of Traffic Signal Equipment

In general, the designer has limited options available in determining acceptable locations for the placement of signal pedestals, signal poles, pedestrian detectors, and controllers. Considering roadside safety, place these elements as far from the roadway as practical. However, due to visibility requirements, limited mast-arm lengths, limited right-of-way, restrictive geometrics, or pedestrian requirements, traffic signal equipment often must be placed relatively close to the traveled way. Consider the following when determining the placement of traffic signal equipment:

1. Clear Zones. If practical, the placement of traffic signals on new construction and reconstruction projects should meet the clear zone presented in Section 38-3.

2. Controller. In determining the location of the controller cabinet, consider the following:

    - The controller cabinet should be placed in a position so that it is unlikely to be struck by an errant vehicle. It should be outside the clear zone, if practical.

- The controller cabinet should be located where it can be easily accessed by maintenance personnel.

- The controller cabinet should be placed so that a technician working in the cabinet can see the signal indications in at least one direction.

- The controller cabinet should be located where the potential for water damage is minimized.

- The controller cabinet should not obstruct intersection sight distance.

- The power service connection should be reasonably close to the controller cabinet.

3. Pedestrians. If the signal pole must be located in the sidewalk, it should be placed in a location that minimizes pedestrian conflict. In addition, signal poles should not restrict a disabled individual's access to curb ramps or reduce the sidewalk width below minimum; see Chapter 58.

4. Layout. Figure 57-4A illustrates a typical urban traffic signal pole installation.

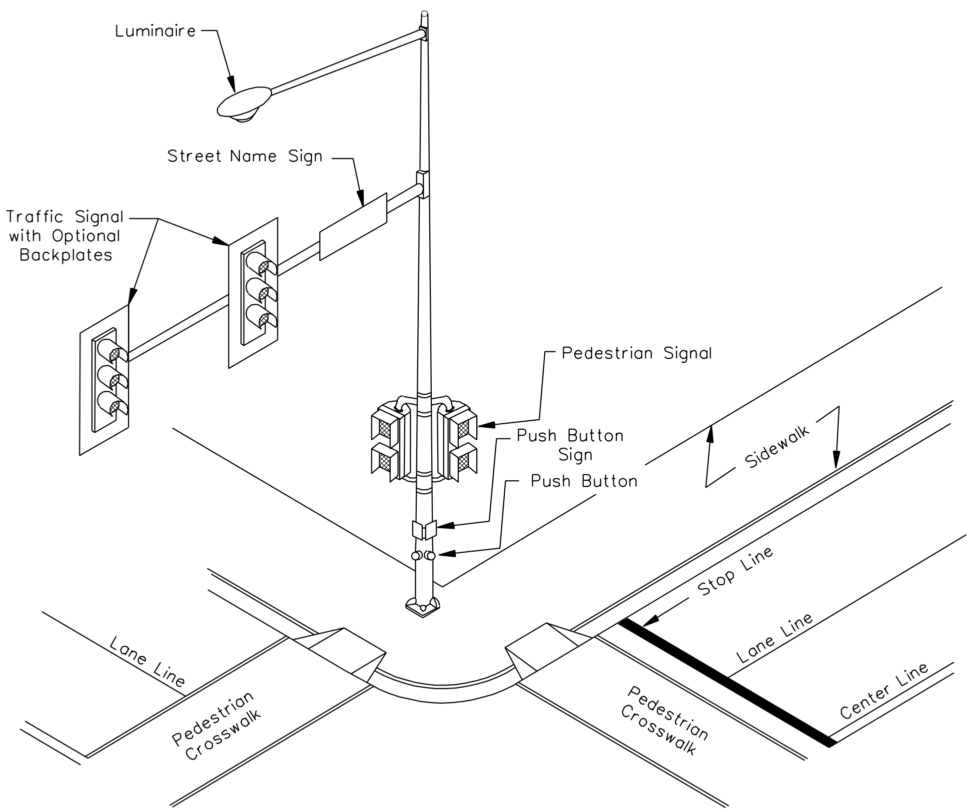
See the *Bureau of Operations Traffic Policies and Procedures Manual, ILMUTCD,* and the applicable references in Section 57-1.02 for specific IDOT criteria for the placement of traffic signal equipment (e.g., placement of signals in medians, use of near-right signals).

57-4.10 Traffic Signal Phasing

The district is responsible for determining the signal phasing plan. The selected phase designation diagram must be included in the traffic signal details and should identify the roadway preferentially. The following sections provide information on signal phasing.

57-4.10(a) Phasing Types

A traffic phase is defined as those green, change, and clearance intervals in a cycle assigned to any independent movement(s) of traffic. Each cycle can have two or more phases. As the number of non-overlapping phases increases, the total vehicular delay at the intersection will increase due to the lost time of starting and clearing each phase. Strive to use the minimum number of phases practical that will accommodate the existing and anticipated traffic demands. As necessary, conduct a capacity analysis to determine if the proposed phasing is appropriate. The following presents typical applications of various phase operations:



TYPICAL TRAFFIC SIGNAL POLE INSTALLATION

Figure 57-4A

1. Eight-Phase Operation. An eight-phase operation provides the maximum efficiency and minimum conflict for high-volume intersections with heavy turning movements. Left-turn lanes should be provided on all approaches. It is most appropriate for actuated control with detection on all approaches. The eight-phase operation allows for the skipping of phases or selection of alternate phases depending upon traffic demand. The *Highway Standards* illustrate a typical eight-phase operation. An eight-phase operation uses the NEMA dual-ring controller.

2. Other Phases. For other phase operations (e.g., six-phase operations), the eight-phase operation can be used by eliminating the non-applicable phases from the sequence.

Highway Standard 857001 illustrates the movements that typically should be assigned to the various numbered phases. As a general rule, on four- and eight-phase operations, the through movements are assigned to the even-numbered phases, and the left turns are assigned to the odd-numbered phases.

The signal controller permits control of each individual phase. Each phase is programmed as a single-entry operation in which a single phase can be selected and timed alone if there is no demand for service in a non-conflicting phase.

There are several computer programs available that can assist the designer in determining the appropriate phasing requirements; see Section 57-4.12.

57-4.10(b) Left-Turn Phases

The most commonly added phases are for left turns (i.e., left-turning vehicles are given a green arrow without any conflicting movements). Left-turn phases can be either a leading left, where the protected left turn precedes the opposing through movements, or a lagging left, where the left-turn phase follows the opposing through movements. The decision on when to use either a leading-left or a lagging-left turn will be determined on a case-by-case basis. In most situations, the preferred practice is to use the leading left. Figure 57-4B provides a comparison for each left-turn phase alternative.

Not all signalized intersections will require a separate left-turn phase. The decision on when to provide an exclusive left-turn phase is dependent upon such factors as traffic volumes, delays, and crash history. Its use will be determined on a site-by-site basis. For intersections with exclusive left-turn lanes, consider the following guidelines when determining the need for a left-turn phase:

1. Capacity. Consider a left-turn phase where the demand for left turns exceeds the left-turn capacity of the approach lane.

LEADING-LEFT-TURN PHASE	
ADVANTAGES	DISADVANTAGES
• Minimizes conflicts between left-turn and opposing straight through vehicles by clearing the left-turn vehicles through the intersection first. • Drivers tend to react quicker than with lagging-left operations.	• Left-turning vehicles completing their movement may delay the beginning of the opposing through movement when the green is exhibited to the stopped opposing movement. • Opposing movements may make a false start in response to the movement of the vehicles given the leading green.
LAGGING-LEFT-TURN PHASE	
ADVANTAGES	DISADVANTAGES
• Both directions of straight through traffic start at the same time. • Approximates the normal driving behavior of vehicular operators. • Provides for vehicle/pedestrian separation as pedestrians usually cross at the beginning of straight through green. • Where pedestrian signals are used, pedestrians have cleared the intersection by the beginning of the lag- green interval. • Cuts off only the platoon stragglers from adjacent interconnected intersections.	• Left-turning vehicles can be trapped during the left-turn yellow change interval as opposing through traffic is not stopping as expected.

COMPARISON OF LEFT-TURN PHASE ALTERNATIVES

Figure 57-4B

2. Delay. Consider a left-turn phase where the delay time for left-turning vehicles is excessive for four hours during an average day. Delay is considered excessive when left-turning vehicles are delayed for more than two complete signal cycles.

3. Miscellaneous. In addition to capacity and delay guidelines, consider intersection geometrics, total volume demand, crash history, posted speeds, etc.

57-4.11 Traffic Signal Timing

57-4.11(a) Pretimed Control

Consider the following guidelines when developing signal timing for pretimed signals:

1. Phases. Keep the number of phases to a minimum. Each additional phase reduces the effective green time available for the movement of traffic flows (i.e., increased lost time due to starting delays and clearance intervals). Adding concurrent phases, if feasible, will normally enhance capacity.

2. Cycle Lengths. Short cycle lengths yield the best performance by providing the lowest average delay, provided the capacity of the cycle to serve the vehicles is not exceeded. In general, consider the following relative to cycle lengths:

    a. Delay. For two-phase operations, shorter cycle lengths generally produce the shortest delays.

    b. Capacity. Longer cycle lengths will accommodate more vehicles per hour if there is a constant demand during the entire green period on each approach. Longer cycle lengths have higher capacity because, over a given time period, there are fewer starting delays and clearance intervals.

    c. Maximum. Normally, a cycle length of 120 seconds should be the maximum used, irrespective of the number of phases. For more than a 120-second cycle, there is an insignificant increase in capacity and a rapid increase in the total delay.

3. Green Intervals. The division of the cycle into green intervals will be approximately correct if made proportional to the critical lane volumes for the signal phases. The critical lane volumes can be determined quickly by using the Planning Methodology from the *Highway Capacity Manual*. In addition, check the green interval against the following:

    a. Pedestrians. If pedestrians will be accommodated, check each green interval to ensure that it is not less than the minimum green time required for pedestrians to cross the respective intersection approaches plus the initial walk interval time.

b. Minimum Lengths. In general, relative to driver expectations, major movements should not have green intervals that are less than 15 seconds. Exceptions to this may be appropriate for turn phases.

4. Capacity. For intersection approaches with heavy left turns, the capacity of an intersection should be checked to determine the need for a separate left-turn lane; see Section 57-4.10.

5. Phase Change Interval. Check each phase change and clearance interval (yellow and all red) to ensure that approaching vehicles can either come to a stop or clear the intersection during the change interval.

6. Coordination. Traffic signals within 0.5 mile (800 m) of each other should be coordinated together in a system. Section 57-4.13 further discusses signal system coordination.

7. Field Adjustments. All signal timing programs should be checked and adjusted in the field to meet the existing traffic conditions.

When determining appropriate cycle and interval lengths, consider the following:

1. General. Cycle lengths generally should fall within the following ranges:

   - Two-Phase Operations — 50 - 80 seconds.
   - Three-Phase Operations — 60 - 100 seconds.
   - Four-Phase Operations — 80 - 120 seconds.

2. Phase Change Interval. The yellow change interval advises drivers that their phase has expired and that they should stop prior to the stop line, or allows them to enter the intersection if they are too close to stop. The yellow change interval should be followed by a red-clearance interval (all-red phase) of sufficient duration to permit traffic to clear the intersection before conflicting traffic movements are released. The equation for calculating phase change intervals is found in the *Bureau of Operations Traffic Policies and Procedures Manual*.

There are several software programs available to assist in determining the most efficient design. Section 57-4.12 discusses several of these programs.

57-4.11(b) Basic-Actuated Control

Actuated-control designs are somewhat different than that of pretimed control. The design of actuated control is basically a trade-off process to optimize the location of vehicular detection to provide safe operation, but yet provide controller settings that will minimize the intersection delay. The compromises that must be made among these conflicting criteria become increasingly difficult to resolve as approach speeds increase. The following discusses some of the design considerations for actuated controls.

Basic-actuated control with passage detection is limited in application to isolated intersections with fluctuating or unpredictable traffic demands and low approach speeds. Basic-actuated control can be employed using either semi-actuated or full-actuated operation.

Because of the small area covered by the small-loop detector and its location from the stop line, this type of detection typically is used with controllers that have a locking memory feature for detector calls (i.e., the controller retains the detector actuation made during yellow and red intervals and when an arriving vehicle did not receive enough green time to reach the intersection).

When developing the signal timing plan and establishing detector locations for basic-actuated control, consider the following:

1. Minimum Assured Green (MAG). Although there is no timing adjustment labeled MAG on the controller, the designer still must calculate the MAG. The minimum green time is composed of the initial green interval plus one vehicle extension. Long minimum greens should be avoided. For snappy operation, the minimum assured green normally should be between 10 and 20 seconds for any major movement. Base the actual value selected on the time it takes to clear all possible stored vehicles between the stop line and the detector. If the MAG is too short, the stored vehicles may be unable to reach the stop line before the signal changes. Use Equation 57-4.1 to calculate MAG:

   $$MAG = 3.7 + 2.1n \quad \text{(Greenshield's Formula)}$$ Equation 57-4.1

   Where: MAG = minimum assured green, s

   n = number of vehicles per lane which can be stored between the stop line and the detector

   Ensure that the minimum green time selected is able to service at least two vehicles per lane. Assuming two vehicles occupy approximately 45 ft (14 m), the detector should not be placed closer than 45 ft (14 m) from the stop line. Closer placement will not reduce the MAG.

   Where pedestrians must be accommodated, a pedestrian detector (e.g., push button) should be provided. Ensure that the timing will be sufficient for the pedestrian to cross the intersection. The minimum times for pedestrians, as discussed in Section 57-4.11(a) for pretimed signals, is also applicable to actuated systems.

2. Vehicular Extension. The vehicular extension fixes both the allowable gap and the passage of time at one value. Ensure that the vehicular extension will be sufficient for a vehicle to travel from the detector to the intersection while the signal is held in green.

However, keep the allowable gap reasonably short to assure quick transfer of green to the side street. Typical headways between vehicles in platoons average between two and three seconds. Therefore, the minimum vehicular extension time should be at least three seconds. For the maximum gap, studies have shown that drivers waiting on red realize gaps of five seconds or more are too long and inefficient. Therefore, the vehicular extension should be set between three and five seconds. For quicker phase changes, shorter gaps could be used.

3. Initial Green. The initial green setting is simply the MAG, usually minus one vehicular extension. Typically, the initial green should be limited to a maximum of 10 seconds.

4. Detector Placement. Set the detector setback distance equal to the time required for the typical vehicle to stop before entering the intersection. The vehicular passage time typically is used to determine this placement. Use the posted speed of the approach roadway to determine the appropriate setback.

5. Maximum Green Interval. This is the maximum time the green should be held for the green phase, given a detection from the side street. Typically, for light to moderate traffic volumes, the signal should "gap out" before reaching the maximum green time. However, for periods with heavy traffic volumes, the signal rarely may gap out. Therefore, a maximum green interval is set to accommodate the waiting vehicles. The maximum green interval can be determined assuming a pretimed intersection. It may be somewhat longer to allow for peaking.

6. Change and Clearance Interval. Determine these intervals in the same manner as for pretimed signals.

7. Left-Turn Lanes. Left-turn lanes should be treated like side streets with semi-actuated control. Use short allowable gaps and minimum greens times. The designer must be careful of vehicles which may enter the left-turn lane beyond the detector. If this may be a problem, consider placing a presence detector at the stop line.

8. Semi-Actuated Controllers. For minor streets with semi-actuated control, the signal normally is held on green for the major street. To ensure that the mainline is not interrupted too frequently, use large minimum greens times on the major street. It normally is expected that the low-volume minor street will experience delay.

9. Intermediate Traffic. Where vehicles can enter the roadway between the detector and intersection (e.g., driveways, side parking) or where a vehicle may be traveling so slow that it does not clear the intersection in the calculated clearance time, the signal controller will not register their presence. A presence detector at the stop line may be required to address these situations; see Section 57-4.11(d).

57-4.11(c) Advanced-Design Actuated Control

Advanced-design actuated control usually is used at isolated intersections with fluctuating or unpredictable traffic demands and high-speed approaches. An advanced-design actuated control is one that has a variable initial interval. It can count waiting vehicles beyond the first and can extend the initial interval to meet the needs of the number of vehicles actually stored between the stop line and the detector. As with basic-actuated control, the small-area detection requires that the controller have a locking memory.

The timing for advanced-design actuated control requires a significant amount of judgment. Therefore, field adjustments often are required after the initial setup. The following discusses several considerations in the signal timing and detector placement:

1. Detector Placement. For high-speed approaches, locate the detector in advance of the dilemma zone as illustrated in Figure 57-4C. This typically will place the detector about 5 seconds of passage time from the intersection. The speed selected should be the posted speed of the approach roadway. Figure 57-4D provides the appropriate detector setback distances for various combinations of passage times and approach speeds. Figure 57-4D also provides the passage times that are appropriate for various other types of actuated controls.

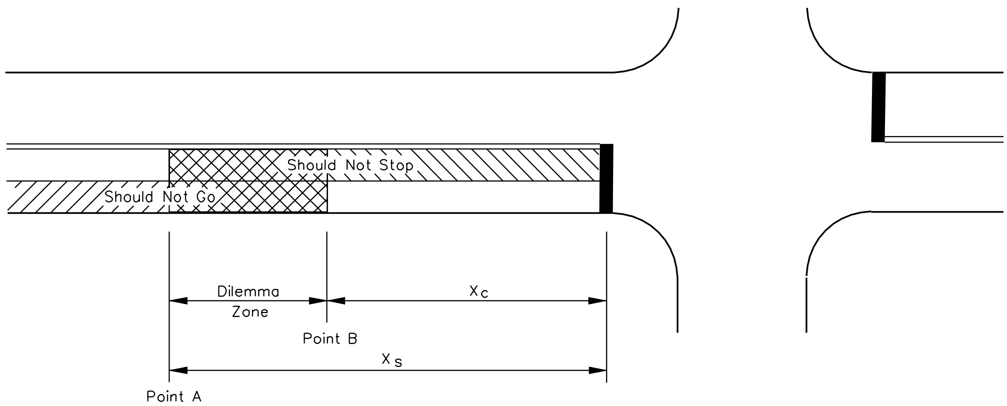
2. Minimum Initial. Because the controller can count the number of vehicular arrivals, the minimum initial time only should be long enough to meet driver expectancy. Typically, the minimum initial interval is set at eight to fifteen seconds for through movements and five to seven seconds for left turns.

3. Variable Initial. The variable initial is the upper limit to which the minimum initial can be extended. It must be long enough to clear all vehicles that have accumulated between the detector and the stop line during the red. The variable initial is determined in the same manner as the minimum assured green for basic-actuated control; see Section 57-4.11(b)).

4. Number of Actuations. The number of actuations is the number of vehicles that can be accommodated during the red that will extend the initial green to the variable initial limit. This is a function of the number of approach lanes, average vehicle length, and lane distribution. It should be set based on the worst-case condition (i.e., vehicles are stored back to the detector).

5. Passage Time. The passage time is the time required for a vehicle to pass from the detector to the stop line. This typically is based on the posted speed of approach roadway.

6. Maximum Green. The maximum green should be set the same as for basic-actuated control; see Section 57-4.11(b).



Notes:

1. X_C = *Maximum distance upstream of stop line from which a vehicle can clear the intersection during the yellow change interval.*

2. X_S = *Minimum distance from stop line where the vehicle can stop completely after the beginning of the yellow change interval.*

3. *At "Point A," 90% of the drivers will decide to stop at the onset of the yellow indication while 10% of the drivers will continue through the intersection.*

4. *At "Point B," 10% of the drivers will decide to stop at the onset of the yellow indication while 90% of the drivers will continue through the intersection.*

5. *For further information on dilemma zones, see FHWA* Traffic Detector Handbook*.*

DILEMMA ZONE

Figure 57-4C

DETECTOR SETBACK DISTANCE — ft (m)							
Approach Posted Speed (mph)	Passage Time in Seconds from Detector to Stop Line						
	1	2	3	4	5	6	7
20	29 (9.0)	58 (17.5)	87 (26.5)	116 (35.5)	145 (44.0)	174 (53.0)	196 (59.5)
25	36 (11.0)	78 (24.0)	108 (33.0)	144 (44.0)	180 (55.0)	216 (66.0)	252 (77.0)
30	44 (13.5)	88 (27.0)	132 (40.0)	176 (53.5)	220 (67.0)	264 (80.5)	308 (94.0)
35	51 (15.5)	102 (31.0)	153 (46.5)	204 (62.0)	255 (77.5)	306 (93.0)	357 (109.0)
40	59 (18.0)	118 (36.0)	177 (54.0)	236 (72.0)	295 (90.0)	354 (108.0)	413 (126.0)
45	66 (20.0)	132 (40.0)	198 (60.5)	264 (80.5)	330 (100.5)	396 (121.0)	462 (141.0)
50	73 (22.5)	146 (44.5)	219 (67.0)	292 (89.0)	365 (111.5)	438 (133.5)	511 (156.0)
55	81 (24.5)	162 (49.5)	243 (74.0)	324 (99.0)	405 (123.5)	486 (148.0)	567 (173.0)
60	88 (27.0)	176 (53.5)	264 (80.5)	352 (107.5)	440 (134.0)	528 (161.0)	616 (188.0)
65	95 (29.0)	190 (58.0)	285 (87.0)	380 (116.0)	475 (145.0)	570 (173.5)	665 (203.0)

Legend

Basic Controllers

Variable Initial Only

Density

Dilemma Zone

DETECTOR SETBACK DISTANCES

Figure 57-4D

7. Allowable Gap. The density feature in controllers permit a gradual reduction of the allowable gap to a preset minimum gap based on one or more cross-street traffic parameters — time waiting, cars waiting, and/or density. Generally, time waiting has been found to be the most reliable and usable. As time passes after a conflicting call, the allowable gap time is gradually reduced. The appropriate minimum gap setting will depend on the number of approach lanes, the volume of traffic, and the various times of day. Fine-tuned adjustments will need to be made in the field.

8. Change and Clearance Interval. Determine these intervals in the same manner as for pretimed signals.

57-4.11(d) Actuated Control with Large Detection Areas

Large area detectors are used in basic-actuated control in the "non-locking" memory mode and with the initial interval and vehicular extension set at or near zero. This is referred to as the loop occupancy control (LOC). Large area detectors are used in the presence mode, which holds the vehicle call for as long as the vehicle remains over the loop. One advantage of large area detectors is that they generally reduce the number of false calls due to right-turn-on-red vehicles. With large area detectors, the length of the green time is determined by the time the area is occupied. However, a minimum green time of eight to fifteen seconds should be provided for driver expectancy. The following discusses several applications for LOC:

1. Left-Turn Lanes. An LOC arrangement is appropriate for left-turn lanes where left turns can be serviced on a permitted green or yellow change or where vehicles can enter the left-turn lane beyond the initial detector. Consider the following when using the LOC for left-turns:

    - To ensure that the driver is fully committed to making the left turn, the initial loop detector may need to be installed beyond the stop line to hold the call.

    - Where motorcycles are a significant part of the vehicular stream, the vehicular extension may need to be set to one second so that a motorcycle will be able to hold the call as it passes from loop to loop. An alternative would be to use the extended-call detector.

2. Through Lanes (Low-Speed Approaches). On low-speed approaches, the dilemma zone protection generally is not considered a significant problem. The detection area length and controller settings are determined based on the desired allowable gap. For example, assuming a 30 mph (50 km/h) approach speed and three-second desired allowable gap, the LOC area is calculated to be as follows:

$$\frac{3 \text{ mi}}{\text{h}} \times \frac{5280 \text{ ft}}{\text{mi}} \times \frac{\text{h}}{3600 \text{ s}} \times 3\text{s} = 132 \text{ ft} \qquad \text{(US Customary) Equation 57-4.2}$$

$$\frac{50 \text{ km}}{\text{h}} \times \frac{1000 \text{ m}}{\text{km}} \times \frac{\text{h}}{3600 \text{ s}} \times 3\text{s} = 42 \text{ m} \qquad \text{(Metric) Equation 57-4.2}$$

By subtracting the vehicular length 20 ft (6 m) from the LOC, the required detection area then is 112 ft (36 m). If a typical loop layout is 45 ft (14 m) long; then, for a 30 mph (50 km/h) approach speed, the vehicular extension setting should be set at 1.5 seconds to provide the three-second gap.

If the initial interval is set at zero and the vehicular extension is between zero and one second then, under light traffic conditions, a green as short as two or four seconds may occur. Check to determine if there are pedestrian or bicyclists present; if so, provide the minimum green times for their crossings. Also consider driver expectancy. Generally, drivers for major through movements expect a minimum green interval of eight to fifteen seconds.

3. Through Lanes (High-Speed Approaches). For high-speed approaches, it generally is not practical to extend the LOC beyond the dilemma zone (five seconds of passage time back from the stop line). To cover the dilemma zone problem, an extended-call detector is placed beyond the dilemma zone. This detector is used in a non-locking mode. The time extension is based on the time for the vehicle to reach the LOC area. Intermediate detectors may be used to better discriminate the gaps.

   There are several concerns with using the LOC concept for high-speed approaches. Some of these concerns include the following:

   - The allowable gap generally is higher than the normally desired 1.5 to three seconds. The controller's ability to detect gaps in traffic is impaired substantially. As a result, moderate traffic routinely will extend the green to the maximum setting — an undesirable condition.

   - For high-speed approaches, LOC designs only should be used if the route is lightly traveled (e.g., 8,000 to 10,000 ADT). High-speed approaches with heavy volumes are served better with density control. The intersection of a high-speed artery with a low-speed crossroad might be served better by using density control on the artery and LOC for the crossroad.

57-4.12 Computer Software

There are numerous software programs available to assist the designer in preparing traffic signal designs and timing plans. New programs, as well as updates to existing programs, are being continuously developed. The following programs are the most widely used for signal timing optimization:

1. SOAP. The Signal Operations Analysis Package (SOAP) program develops fixed-time, signal-timing plans for individual intersections. SOAP can develop timing plans for six design periods in a single run. It also can analyze 15-min volume data for up to 48 continuous time periods and determine which timing plan is suited best for each 15-min period. A data input manager is included with the program to facilitate data entry.

2. PASSER II and MAXBAND. Progression Analysis and Signal System Evaluation Routine (PASSER II) and MAXBAND are known as bandwidth-optimization programs. They develop timing plans that maximize the through progression band along arterials of up to 20 intersections. Both programs work best in unsaturated traffic conditions and where turning movements onto the arterial are relatively light. PASSER II and MAXBAND also can be used to develop arterial phase sequencing for input into a stop-and-delay optimization model such as TRANSYT-7F.

3. TRANSYT-7F and SIGOP-III. The Traffic Signal Network Study Tool (TRANSYT-7F) and the Signal Timing Optimization Program (SIGOP-III) develop signal-timing plans for arterials or grid networks. The objective of both programs is to minimize stops and delays for the system as a whole, rather than maximizing arterial bandwidth.

4. Arterial Analysis Package. The Arterial Analysis Package (AAP) allows the user to easily access PASSER II and TRANSYT-7F to perform a complete analysis and design of arterial signal timing. The package contains a user-friendly forms display program so that data can be entered interactively on a microcomputer. Through the AAP, the user can generate an input file for any of the two component programs to quickly evaluate various arterial signal-timing designs and strategies. The package also links to the “Wizard of the Helpful Intersection Control Hints” (WHICH) to facilitate detailed design and analysis of the individual intersections. The current program interfaces with TRANSYT-7F, PASSER II, and WHICH.

5. Highway Capacity Software. The Highway Capacity Software (HCS) replicates the procedures described in the *Highway Capacity Manual*. It is a tool that greatly increases productivity and accuracy, but it should be used only in conjunction with the *Highway Capacity Manual* and not as a replacement for it.

6. CORSIM. CORSIM is a microscopic program that can be used to simulate traffic operations for arterials, isolated intersections, and/or roadway networks. It can be used to determine delay, queue length, queue time, stops, stop times, travel time, speeds, congestion measures, etc. However, it does not have optimizing capabilities (i.e., the user must conduct multiple simulations to determine the “best” signal timing). It can be used with both fixed-timed and/or actuated-controlled intersections.

7. COPTRAFLO. COPTRAFLO can be used to develop time-based diagrams for arterials. It can be used to determine the optimal traffic band for both one-way or two-way arterials. The program also will allow the user to review all available solutions and will provide the offsets for the system signals based on speed and cycle lengths.

8. SYNCHRO. SYNCHRO provides interactive time-space diagrams for arterials. It can be used to optimize signal splits, cycle lengths, phase orders, and offsets. Outputs include vehicle delay, level of service, queue length, queuing penalty, stops, fuel usage, and dilemma vehicles.

Most of these software programs can be purchased from either McTrans Center or from PC-TRANS. Many of these software programs can be purchased for either the network operating systems or stand-alone operating systems.

57-4.13 Signal System Design

As traffic volumes continue to grow, installing coordinated signal systems is an important consideration for improving traffic flow. By coordinating two or more traffic signals together, the overall capacity of the facility can be increased significantly. As compared to constructing additional lanes, coordinating traffic signals is a relatively inexpensive method of improving capacity because it reduces vehicular delay with minimal disruption to the highway system. Although not a capacity panacea, the use of a coordinated traffic signal system could satisfy the needs of highway users for many years. Generally, traffic signals that are within 0.5 mile (800 m) of each other are good coordination candidates. The following sections present application guidelines for traffic signal systems.

57-4.13(a) System-Timing Parameters

The basic system-timing parameters used in a coordinated system include:

1. Cycle. The period of time in which pretimed control (or actuated control, with demand on all phases) displays a complete sequence of signal indications. In most systems, the cycle length is common to all intersections operating together and is called the background cycle.

2. Split. The proportioning of the cycle length among the various phases of the local controller.

3. Offset. The time relationship determined by the difference between a specific point in the local signal sequence (typically the beginning of the major street green interval) and a system-wide reference point.

4. Time-of-Day/Day-of-Week. The time-of-day/day-of-week system selects system timing plans based on a predefined schedule. The timing plan selection may be based not only on the time-of-day but also on the day-of-week and week-of-year. Some systems permit the selection of plans based upon a specific day of the year.

5. Traffic Responsive. Traffic-responsive systems implement timing patterns based on varying traffic conditions in the street. Most traffic-responsive systems select from a number of predeveloped timing plans.

57-4.13(b) Advantages of Traffic Signal Systems

A primary objective of installing a traffic signal system is to develop a good progression of traffic. Some advantages of providing good traffic progression are as follows:

1. Operational and Environmental Benefits. Traffic signal systems reduce fuel consumption, pollutant emissions, and vehicle operating costs.

2. Increase In Capacity. A higher level of traffic service is provided in terms of higher overall speed and reduced number of stops. Traffic will flow more smoothly and an improvement in level of service often results.

3. Speed Uniformity. The speed of vehicles will be more uniform because there will be no incentive to travel at excessively higher speeds to make a green signal indication that is not in step. On the other hand, the slow driver is encouraged to speed up to avoid having to stop for a red-signal indication.

4. Crash Reduction. Fewer crashes will result because platoons of vehicles will arrive at each traffic signal at a green signal indication, thereby reducing the possibility of red-signal violations and rear-end collisions. Naturally, if there are fewer occasions when a red-signal indication is displayed to a majority of motorists, there is less likely to be crashes than can be attributed to due to driver inattention, brake failure, slippery pavement conditions, and other similar factors.

5. Greater Traffic Control Obedience. Greater obedience to signal indications will be obtained from both motorists and pedestrians. This results because motorists will aggregate in platoons of closely-spaced vehicles due to their desire to ride the “green wave” produced by the coordinated signals. Pedestrians will remain at curbside during the passage of each platoon and realize a sufficient gap between platoons to safely cross.

6. Greater Use of Arterial Streets. Through traffic will tend to remain on arterial streets rather than shifting their route over to parallel minor streets.

57-4.13(c) System Types

There are several different methodologies available to coordinate traffic signals. Most of these take advantage of computer technology. As new signal controllers, computers, and software are developed, the design of coordinated traffic signal systems will continue to improve. These systems should match existing systems and/or be coordinated with nearby systems as practical. The following briefly describes several types of traffic signal coordination systems:

1. Interconnected Time-of-Day System. The interconnected time-of-day system is applicable to both pretimed and actuated control, in either a grid system or along an arterial system. The typical configuration for this type of system includes a field-located, time clock-based master controller generating pattern selection and synchronization commands for transmission along a cable interconnect. Local intersection coordination equipment interprets these commands and implements the desired timing.

2. Time-Base-Coordinated Time-of-Day System. Time-base coordination often is used as a backup for computerized signal systems. Operationally equivalent to the interconnected time-of-day system, this type of system uses accurate time-keeping techniques to maintain a common time of day at each intersection without physical interconnection. Time-base coordination is tied to the 60 Hz AC power supply, with a battery backup in case of a power failure.

   Time-base coordination allows for the inexpensive implementation of a coordinated signal system, because the need for a cable interconnect is eliminated. However, time-base systems require periodic checking by maintenance personnel, because the 60 Hz reference from the power company sometimes is inconsistent. In addition, power outages sometimes affect only portions of a system, resulting in drift between intersections that continue to operate on power company lines and those that maintain time on a battery backup.

3. Traffic-Responsive Arterial Systems. The traffic-responsive arterial system normally is used with semi-actuated controllers along an arterial. The field located system master selects predetermined cycle lengths, splits, and offsets based upon current traffic flow measurements. These selections are transmitted along a cable interconnect to the slave controllers at the local intersections.

   Cycle lengths typically are selected based on volume (and sometimes occupancy) level thresholds on the arterial; the higher the volumes, the longer the cycle length. Splits frequently are selected based on the side-street volume demands, and offsets are selected by determining the predominant direction of flow along the arterial.

   System sampling detectors, located along the arterial, transmit data back to the master controller along the interconnect cable. Most current systems have the capability to implement plans on a time-of-day basis as well as through the use of traffic-responsive techniques.

4. <u>Distributed-Master (Closed-Loop) Systems</u>. The distributed-master (frequently called closed-loop) system advances the traffic-responsive arterial system one step further by adding a communications link between the field-located master controller and an office-based microcomputer. Most systems are designed to interface with a standard personal computer over dial-up telephone lines. This connection is established only when the field master is generating a report or when the operator is interrogating or monitoring the system. With proper equipment, several systems can share a single office-based microcomputer.

   The system permits the maintenance of the complete controller database from the office. The controller's configuration data, phase and timing parameters, and coordination patterns can be downloaded directly from the office.

   The distributed-master system provides substantial remote monitoring and timing plan updating capabilities for only a minor increase in cost — typically, only the expense of the personal computer and the monthly costs of a standard business telephone line. Graphics displays usually are provided to assist in monitoring the system.

57-4.13(d) Communications Techniques

Systems other than time-base-coordinated systems require some type of communications medium to maintain synchronized operation between intersections. Two primary communications options are available. One is to employ hardwired communications through leased telephone lines, fiber optics, or direct wiring. A second option, which has been unreliable in some cases, is to utilize the through-the-air frequencies of radio communications and cellular telephone equipment. The requirements for the communications network depend on the needs of the system. Therefore, decisions on an appropriate communications technique will be made on a case-by-case basis.

57-4.14 <u>Advance Warning</u>

At signalized intersections where the use of an advance warning sign is justified to alert drivers of an approaching traffic signal (e.g., restricted sight distance to signal face, high-speed multilane divided highways), consider the relative benefits of mounting a flashing yellow warning beacon on the appropriate advance warning sign and interconnecting the beacon with the signal controller so that the beacon is energized during the red-signal indication of the warned approach.